SI-EGR NG Engine w/TWC

Project Update
NGNGV Steering Committee

July 23, 2003

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Cummins

Review Topics

- Program Overview
- Targets
- Technology/benefits
- Schedule
- Status
- Next steps

Program Overview

- Demonstrate a high efficiency low emissions SI Natural Gas engine with cooled EGR
- Apply Cummins EGR technology to SI Natural Gas
- Diluting with EGR instead of air allows stoichiometric operation and use of a three way catalyst
- Demonstrate diesel like peak thermal efficiency, bmep and 2007 emission targets

Program Overview (cont.)

- 2 year program
- Cummins main subcontractor
- Westport subcontractor to Cummins for catalyst develop.
- Contract signed by SCAQMD July 7th 2003

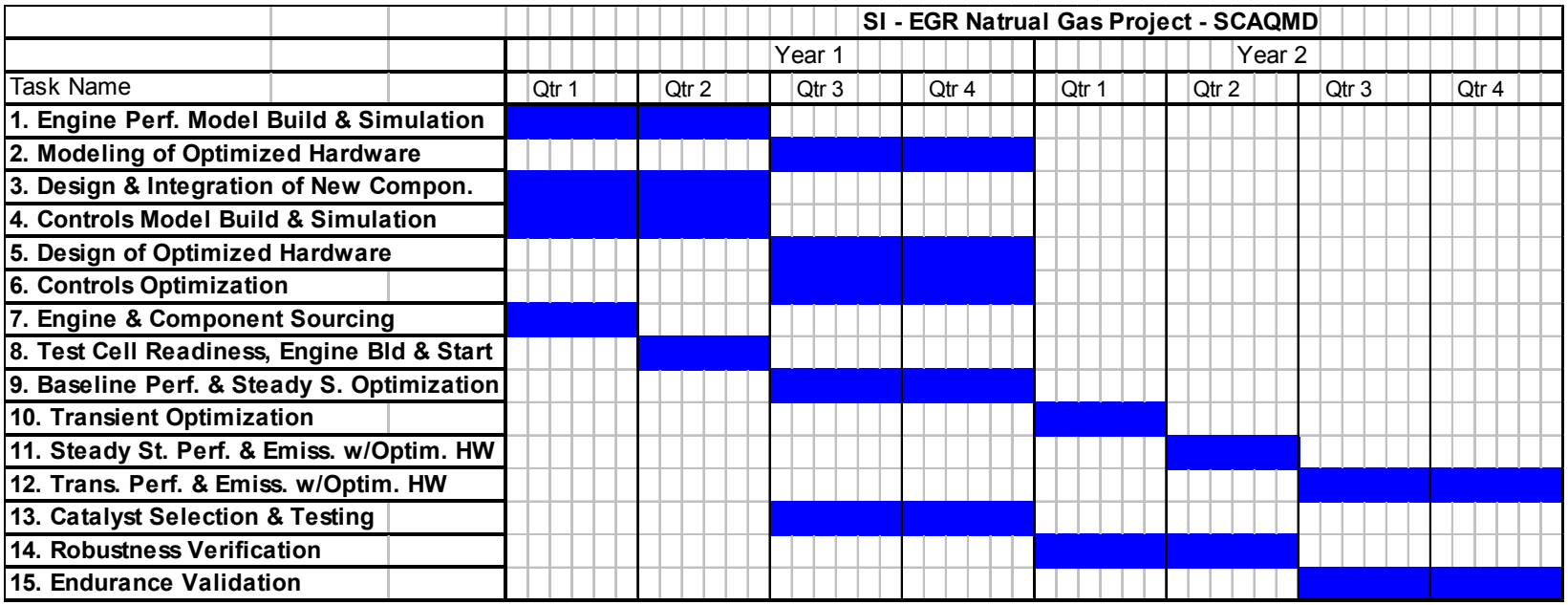
Technology / Benefits

- Stoichiometric operation allows use of a three-way catalyst
- EGR HD systems availability made possible this approach
- Cooled EGR
  - Dilutes charge and lowers combustion temperatures for lower NOx output
  - Suppresses knock tendency allowing higher bmep
  - Higher bmep results in improved thermal efficiency
  - Cooled EGR improves ignition system durability
- Technology can be applied on various platforms and applications

Project Targets

	SI - EGR TARGET	Current C8.3 Gas Plus
Rated Power (BHP)	310	280
Torque Peak lbs-ft (lbs-ft)	950	850
BMEP @ Rated Power (psi)	202	183
BMEP @ Torque Peak (psi)	283	254
Torque Peak Ther. Effic. (%)	40	36
FTP Emissions g/bhp-hr	w/TWC	w/OC
NOx, NMHC, Formaldh.	0.2, 0.14, 0.01	1.5, 0.2, 0.019
PM	0.01	0.01

Schedule



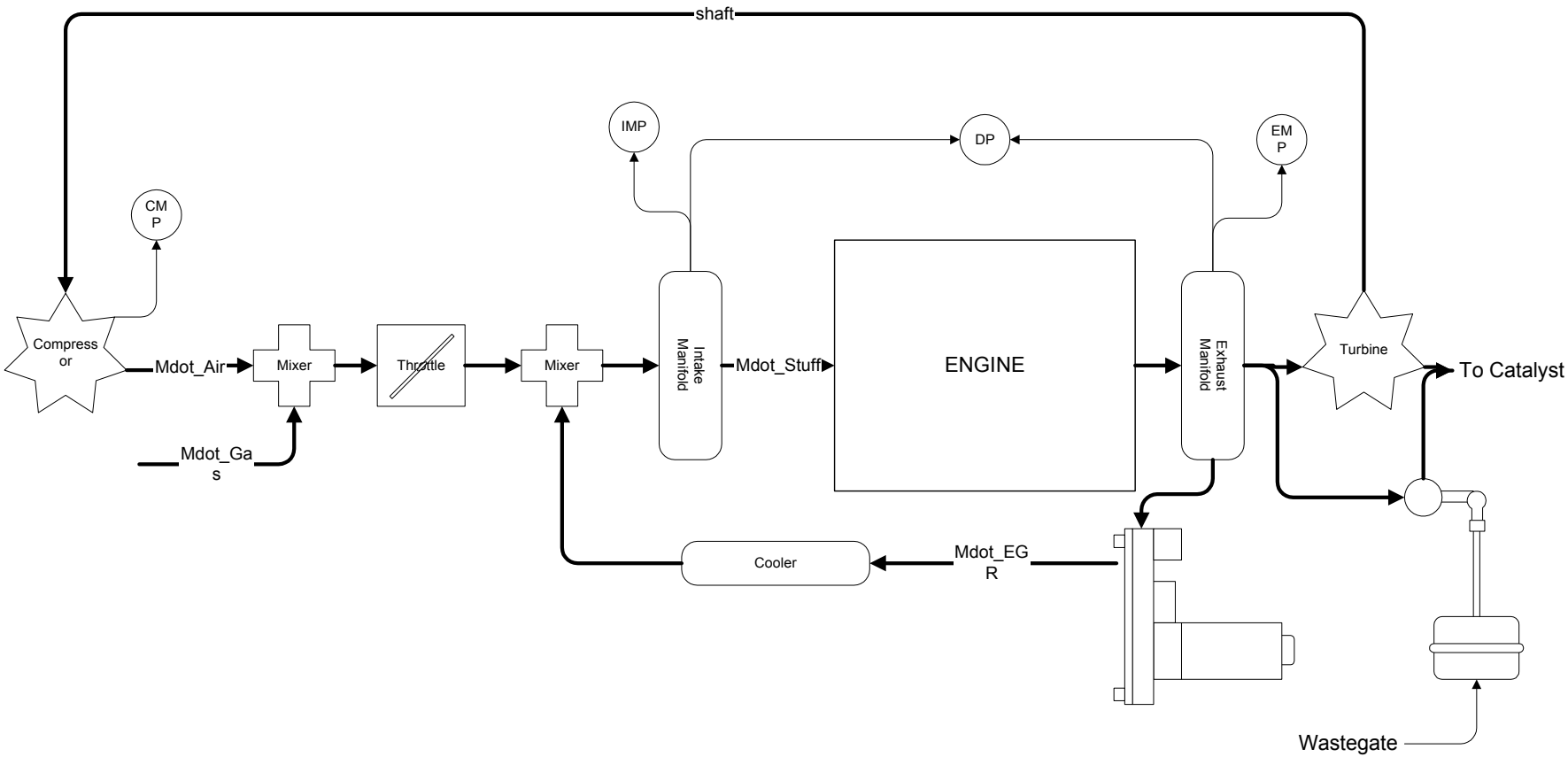
Status

- Literature review completed
- Modeling, Design and controls activities on-going
- Procured C Gas Plus engine
- Analysis confirms efficiency improvement

Project Challenges

- Ability to control the A/F ratio during transients
- Cylinder to cylinder variation
- Driving sufficient EGR near the torque curve
- Maintaining stable air handling operation
- Increase in max bulk in-cylinder temperature
- Increased coolant flow needed

System set-up

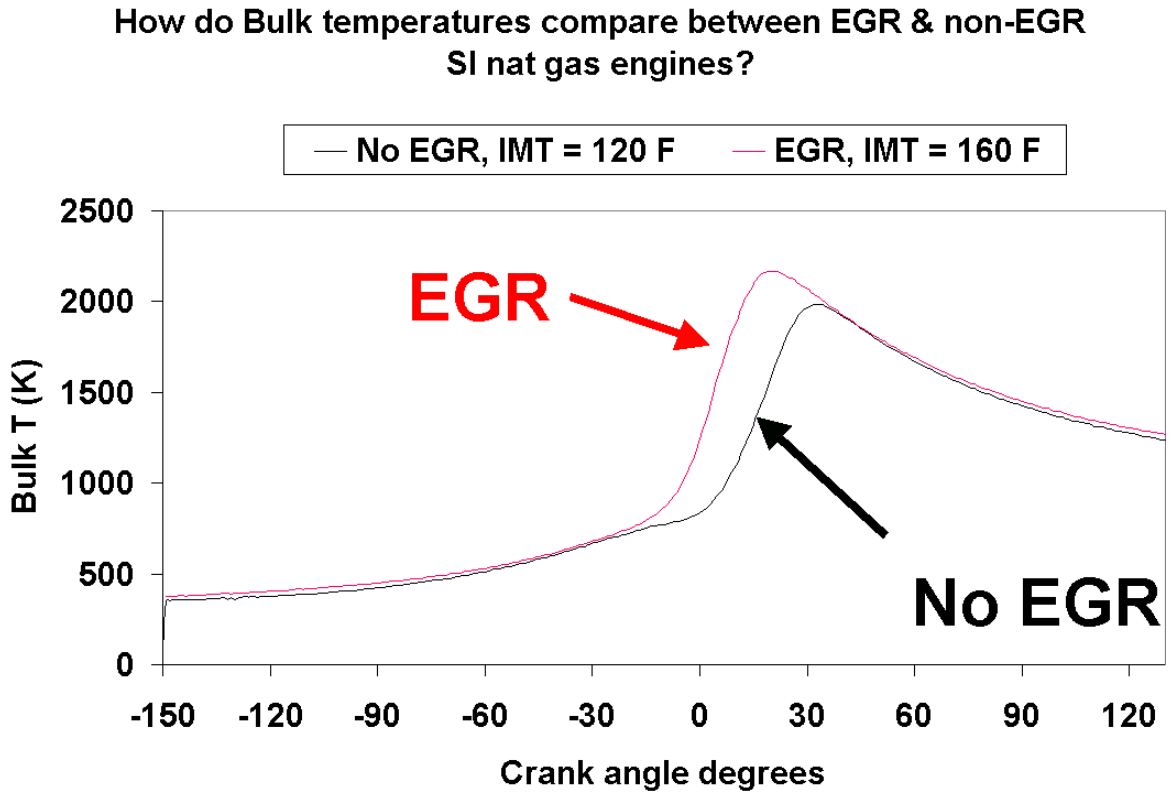


Peak bulk temp analysis

Peak bulk T is about 10 % higher

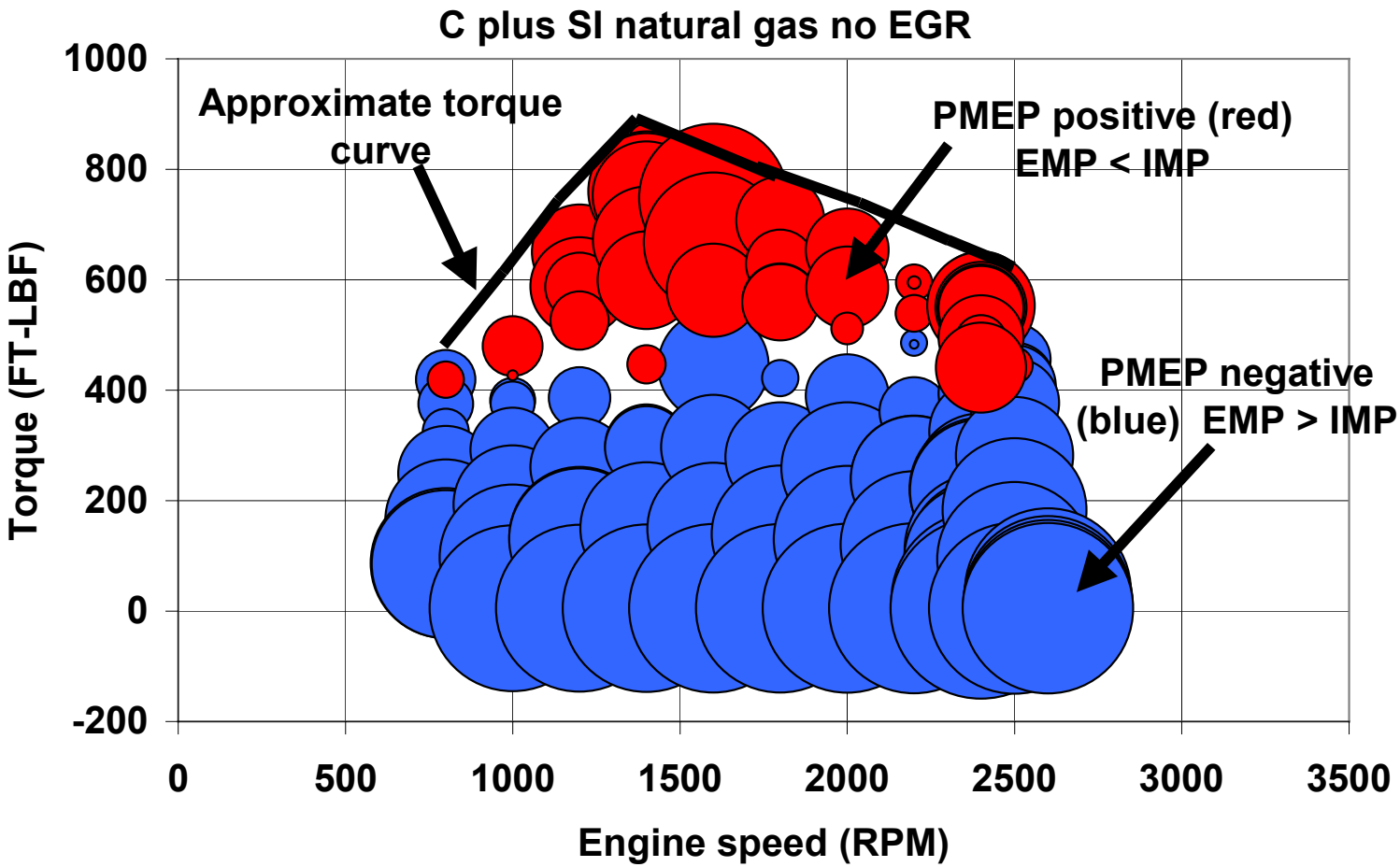
Due to:

- **higher CR**
- **higher IMT**
- **more advanced heat release**



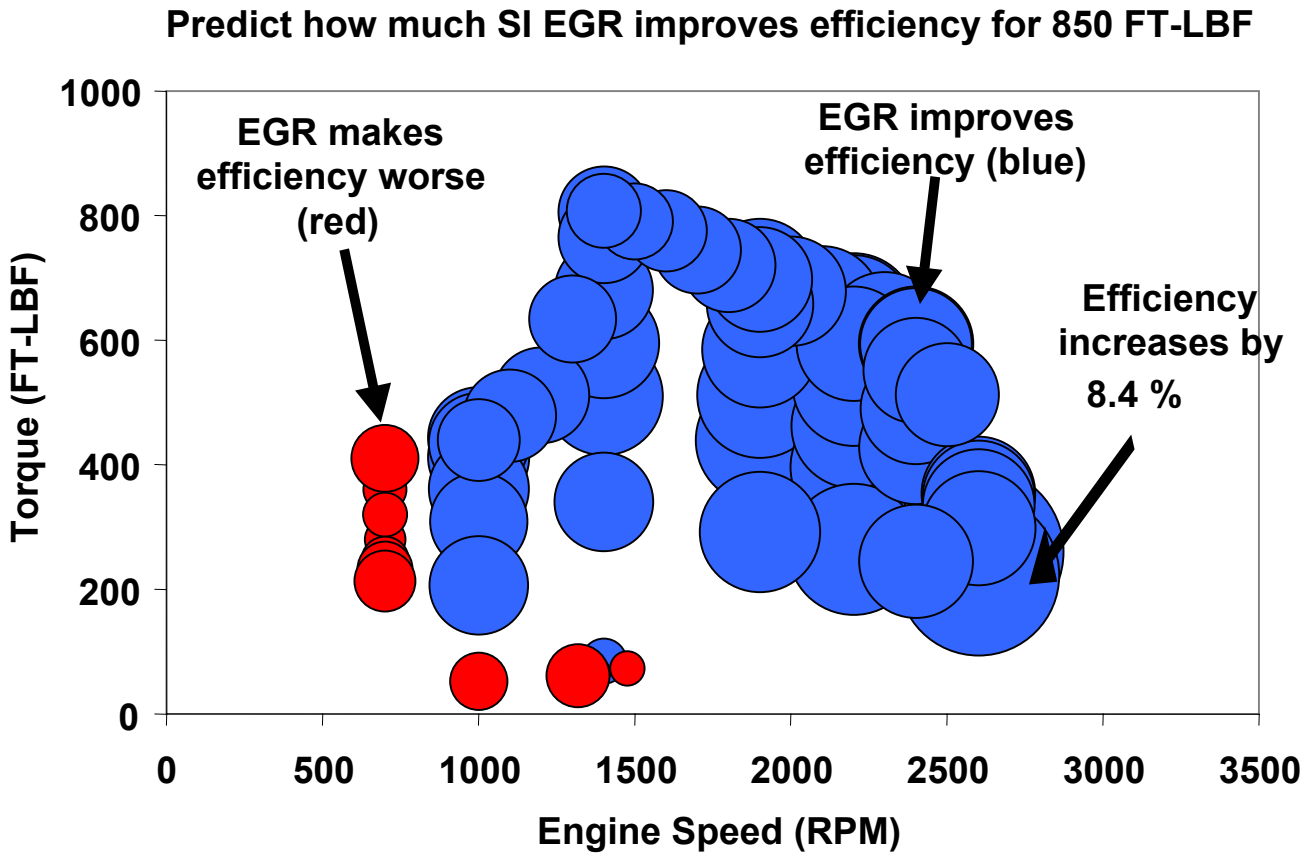
EMP vs IMP Mapping

EMP > IMP on C Plus engine most of the time



Efficiency Analysis

Brake Thermal Efficiency w/EGR (17.5 bar @ Torque Peak)



Next Steps

- Continue GT-Power model development
- Simulate High Pressure and Low Pressure EGR loops
- Continue Controls System models
- Piston bowl analysis
- Continue Design Activities= HD EGR system adapted to C8.3 Gas Plus engine